

Introduction to Climate Change

Global warming, peak (whale) oil, and our future

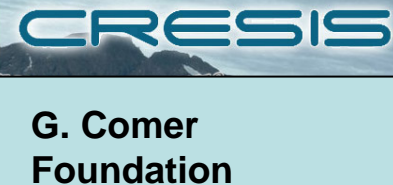
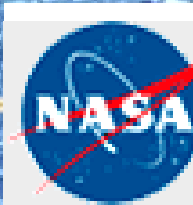
Richard B. Alley, Penn State

Please note:

I work for Pennsylvania State University,
And help UN IPCC, NRC, etc.,
But I am not representing them,
Just me.



The Heat is On! Confronting Climate
Change in the Classroom
CReSIS, June 2, 2008



G. Comer
Foundation

Energy

- You eat about 2400 Calories per day;
- You use about 240,000 Calories per day;
- Like having 100 serfs to do your bidding;
- Driving, heating, cooling, pumping, plowing, trucking, flying, cooking...
- Almost all from oil, coal and natural gas (fossil fuels).



Settlers cut almost all Pennsylvania trees, often for fuel, losing all (elk, bison, fisher, mountain lion), or almost all (deer, turkey) large wildlife.

Penn's Woods-->Pennsylvania "Desert"

<http://www.smithsonianmagazine.com/multimedia/rich-media/0206-forgotten-forest/index.php>
© Lois Barden Collection

<http://www.explorepahistory.com/>
(Pennsylvania State Education Association)

Not enough whales to
light the evening, either.

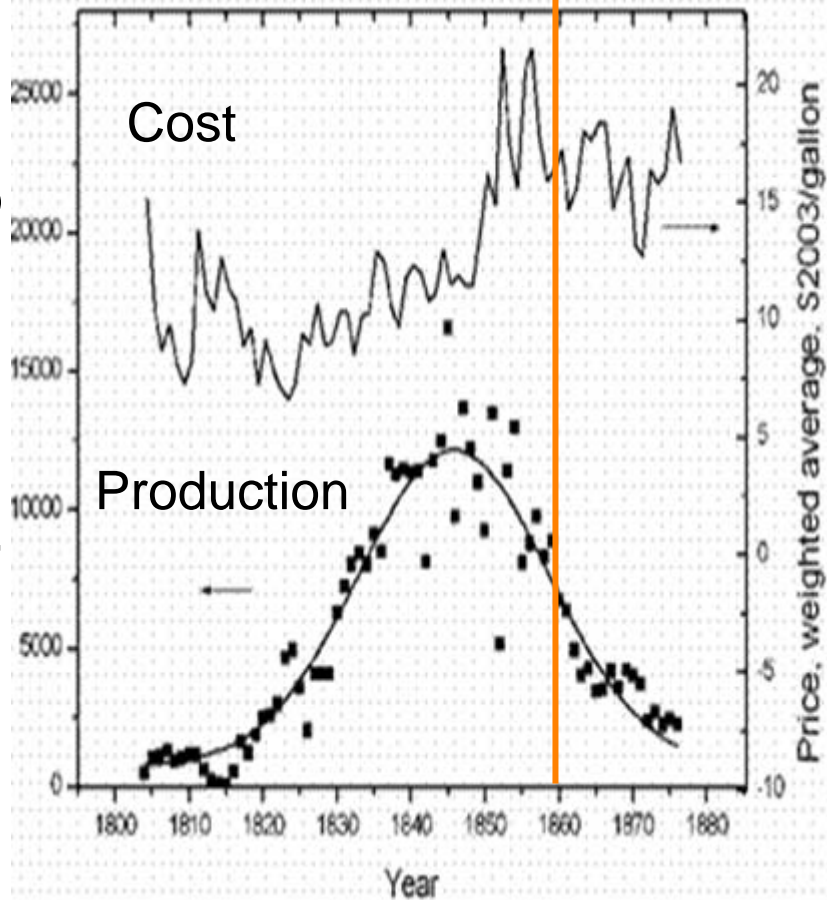
So, we drilled for oil...

Drake Well,
1859



<http://www.parks.tas.gov.au/historic/swhaling/offshore.html>
Tasmanian Museum and Art Gallery

Whale-oil production, gallons



Whale oil production. Prices and Production over a complete Hubbert Cycle: the Case of the American Whale Fisheries in 19th Century, Aug 2004, Ugo Bardi, ASPO: The Association for the Study of Peak Oil and Gas, and Dipartimento di Chimica - Universita di Firenze, Via della Lastruccia 3, Sesto Fiorentino (Fi), Italy. bardi@unifi.it This document is published in the #45 issue of the ASPO newsletter. (www.peakoil.net) The present version appears at <http://www.aspoitalia.net/aspoenglish/documents/bardi/whaleoil/whaleoil.html> Data from A. Starbuck, History of the American whale fishery, Seacaucus, N.J. 1878, reprinted 1989

Consider transportation:

- Typical U.S. driver buys almost 100 pounds of gasoline per week
- And burning adds O_2 to make about 300 pounds of CO_2
- *(1 gallon of gas weighs about 6 pounds, so 16 gallons is nearly 100 pounds, and each pound of gasoline yields 3.1 pounds of CO_2)*

If car CO₂ came as horse ploppies:

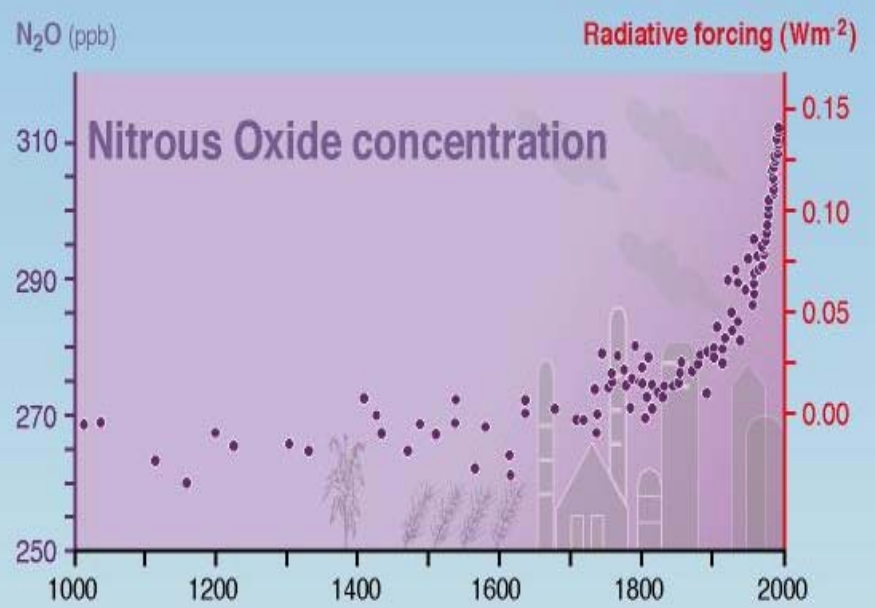
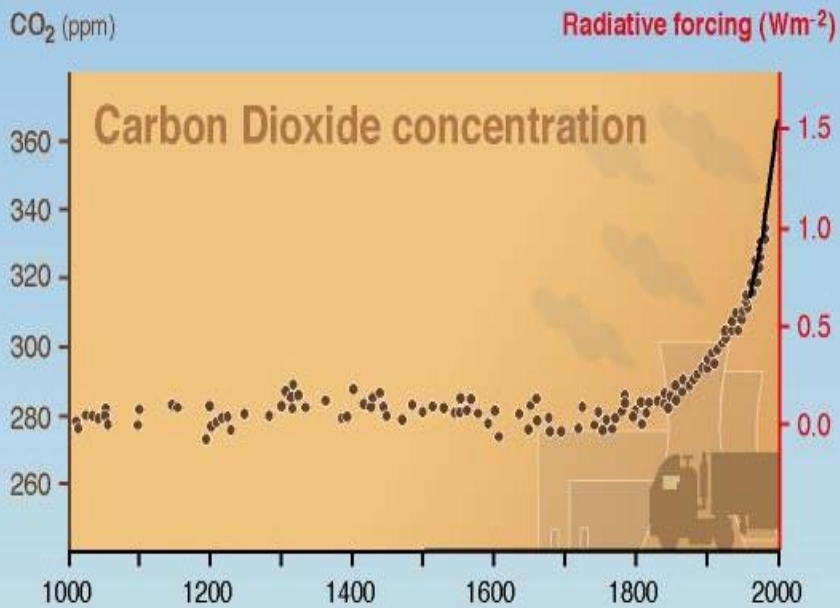
- ~1 pound/mile driven;
- US drivers would cover every road in the country an inch deep every year;
- And you would smell it everywhere.
- Don't even THINK about airplanes...

Fossil Fuels Will Run Out:

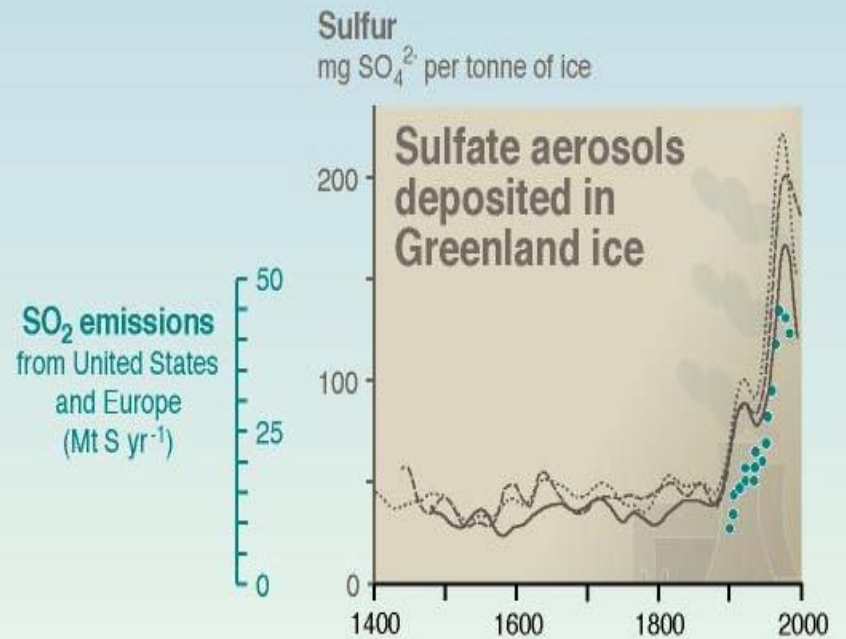
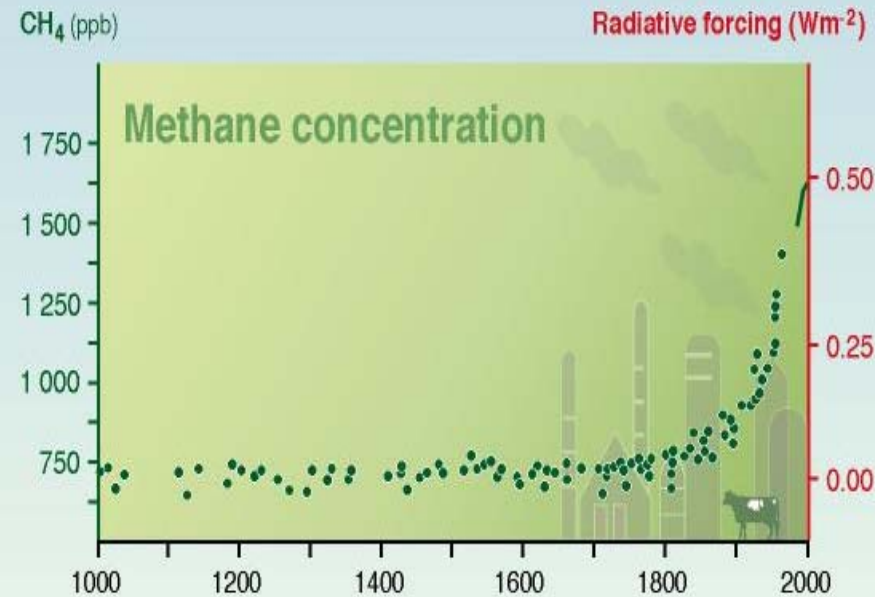
- They are finite;
- Use is rising rapidly--other people want 100 “willing workers”, too!
- Will we help those other people?
- We now pay over \$100/barrel for oil--poor people cannot afford that to get the benefits of the energy (and becoming harder for us...at \$100/barrel, imports=\$1,700 per year for each and every one of us!).

Now to global warming:

- **IF** we burn all the fossil fuels before switching to other energy;
- **THEN** we are confident we will change world in ways we don't like;
- **AND** we still will have to switch from fossil fuels anyway.



IPCC, 2001

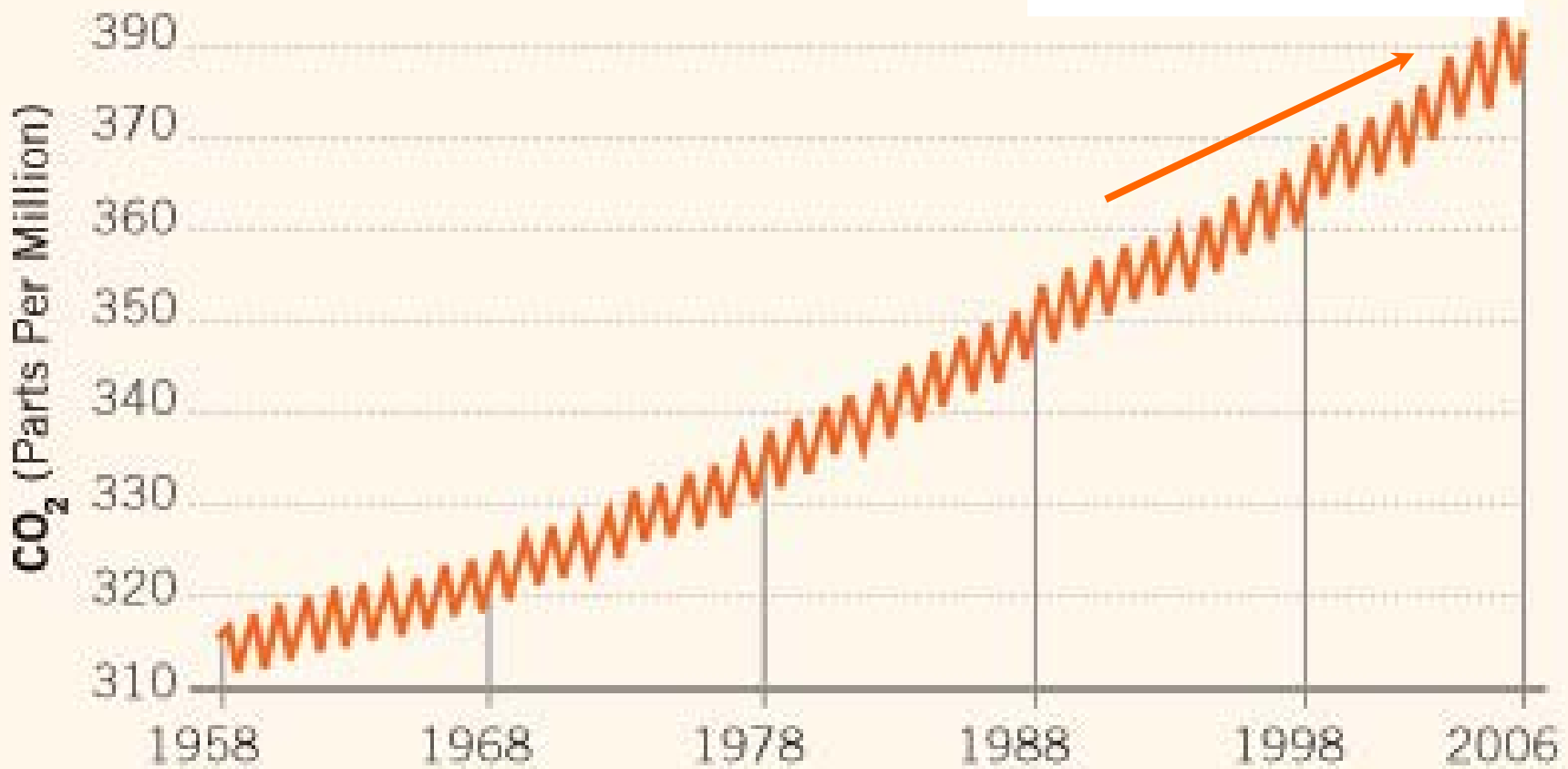
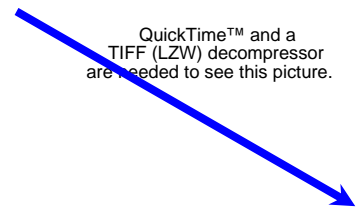


Is it our CO_2 ? Yes

- Quantitative match between known burning and observed extra CO_2 in system;
- Nothing else adequate (volcanic source 1-2% of ours...);
- Atmospheric indicators demonstrate dominant role for fossil-fuel CO_2 :
 - Atmospheric O_2 drop--excess CO_2 is from combustion (not from ocean, volcano)
 - Atmospheric ^{13}C dilution--excess CO_2 is from biosphere or fossil fuel (not from ocean, volcano, carbonate rock)
 - Atmospheric ^{14}C dilution--excess CO_2 is from old source (not from modern biosphere)

Record since 1958 of atmospheric CO₂ (below) and the shorter record of atmospheric O₂ (right). These are related--oxygen is being used to burn fossil fuels to make the CO₂. We'll be able to breathe, but CO₂ is from burning plants, not from ocean or volcanoes.

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.



Warming over last century:

- **UNEQUIVOCAL, from cautious IPCC**

- Direct thermometer measurements:

→ In air (including far from cities);

→ In ocean water;

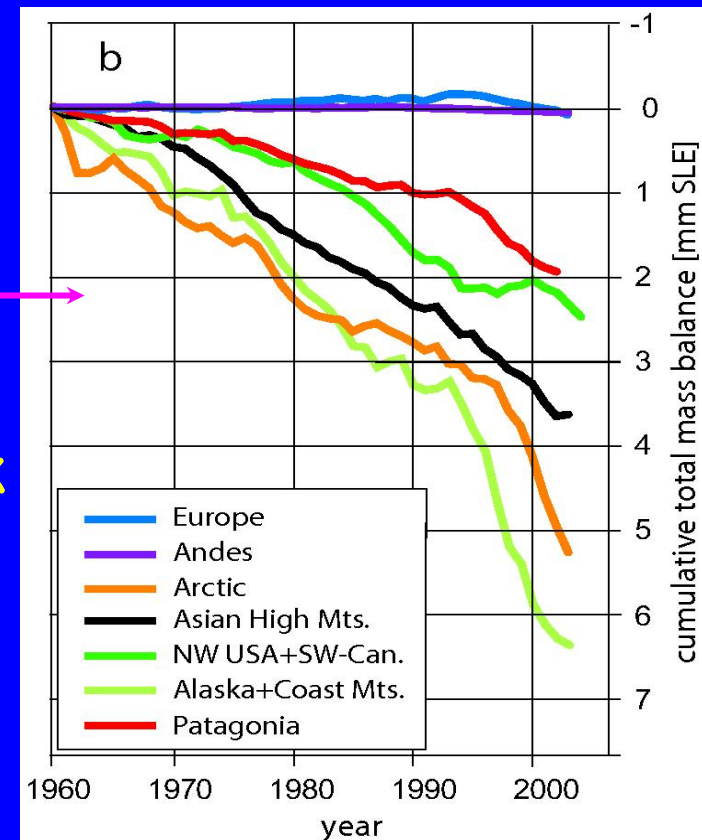
→ In ground;

→ On balloons;

→ From satellites;

- Mass loss from almost all glaciers, including those getting more snow.

- (There still is weather--some people who should know better look at a La Niña-cooled year and claim warming stopped. Silliness.)





Muir Glacier, Alaska, August 13, 1941, photo by W.O. Field



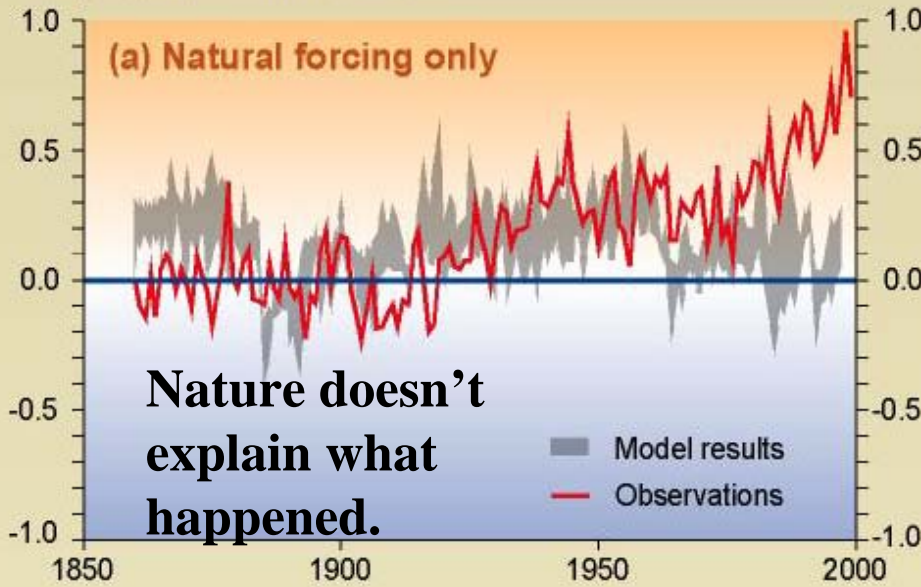
Muir Glacier, Alaska, August 31, 2004, photo by B.F. Molnia

High confidence warming from our CO₂

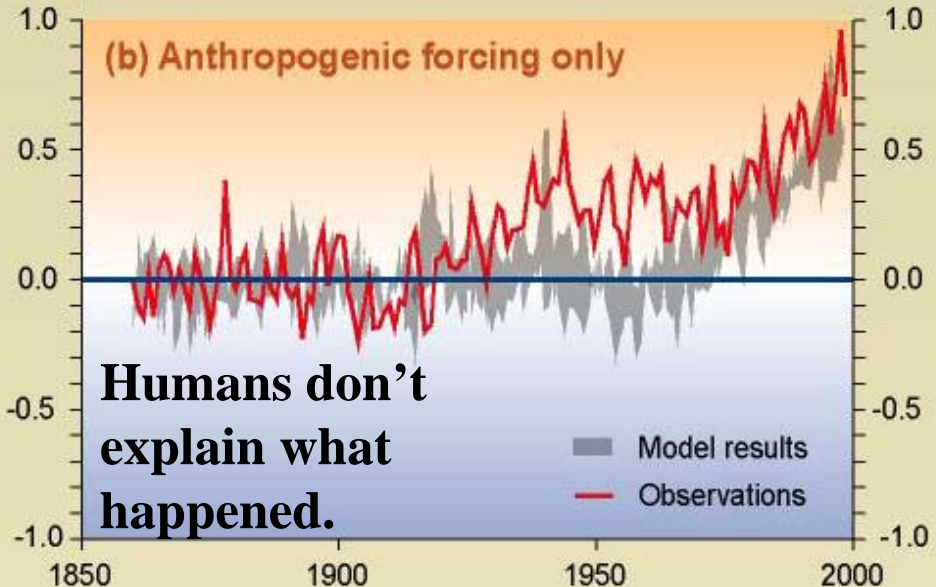
- PHYSICS: warming effect of observed CO₂ rise unavoidable;
- FORCINGS: No other plausible cause pushing warming (sun is not getting brighter, cosmic rays are not changing, etc.)
- FINGERPRINTS: Quantitative match between modeled and observed warming in time and space if and only if CO₂ included, and quantitative mismatch for any other putative cause of warming:
 - If warming were from ocean, as in El Niño, ocean would cool as air warms, but ocean is warming as air warms;
 - If warming were from solar increase--which is NOT observed by satellite--upper stratosphere would warm as well; CO₂ increase holds heat near surface and cools upper stratosphere; we see warming down here and cooling up there;
 - And so on for other proposed explanations (NOT volcanoes, cosmic rays, orbits, magnetic field, ...) (but notice that some ideas in blogosphere are too fuzzy to be falsified).

Comparison between modeled and observations of temperature rise since the year 1860

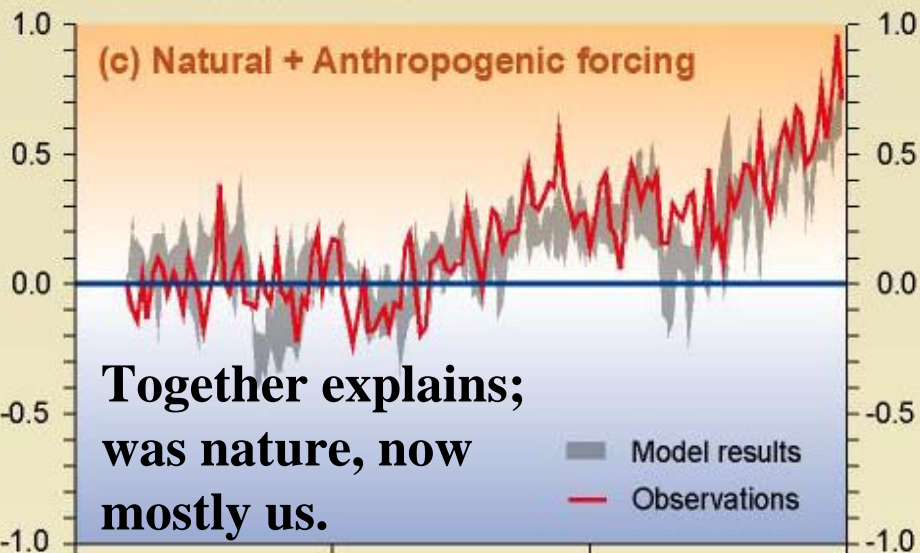
Temperature anomalies in °C



Temperature anomalies in °C



Temperature anomalies in °C



— Red shows what happened.

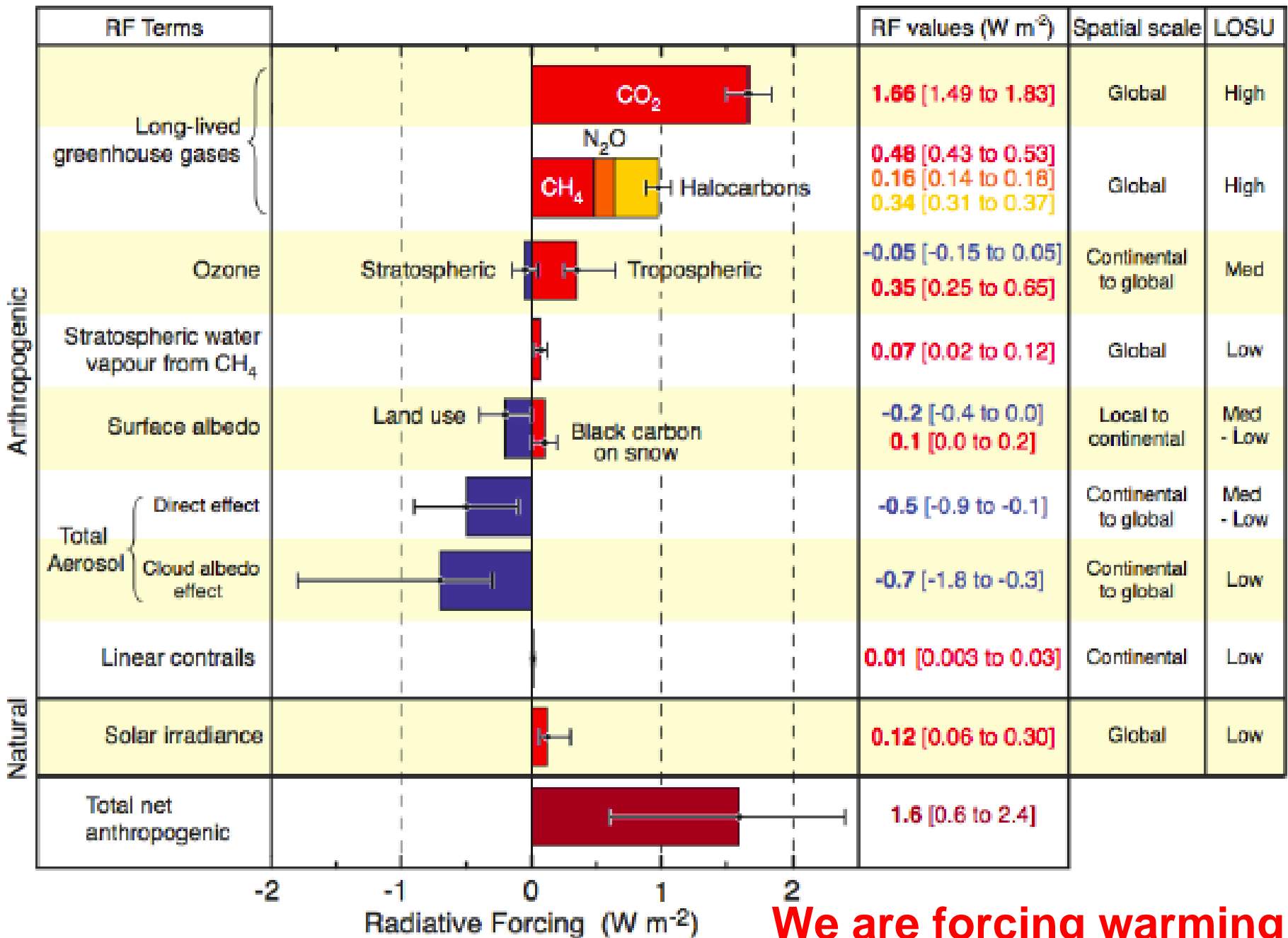
— Gray shows what model thinks happened.

IPCC, 2001

More warming?

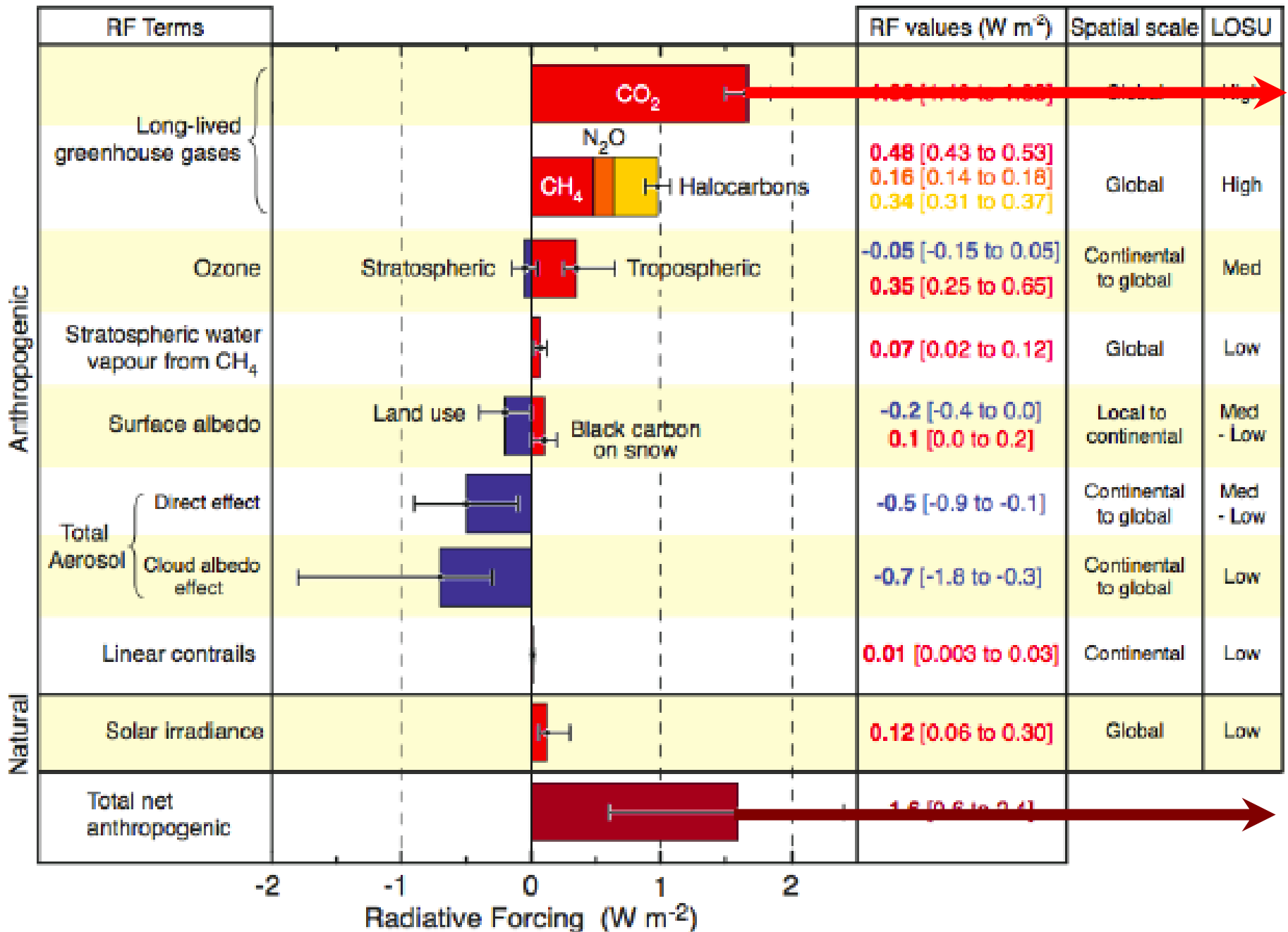
- Attribution has been difficult-- CO_2 forcing of last century of same order of magnitude as many others (solar, methane, soot, other human particles, volcanoes, etc.);
- Think of a soccer game with a lot of 5-year-olds kicking the ball almost aimlessly--you have to watch for a while to see that CO_2 is slightly stronger and more sustained;
- Future "easier"-- CO_2 only one with long enough residence time and strong enough sources to really matter--replace just one of the 5-year-olds with a World Cup player trying to win;

Radiative Forcing Components



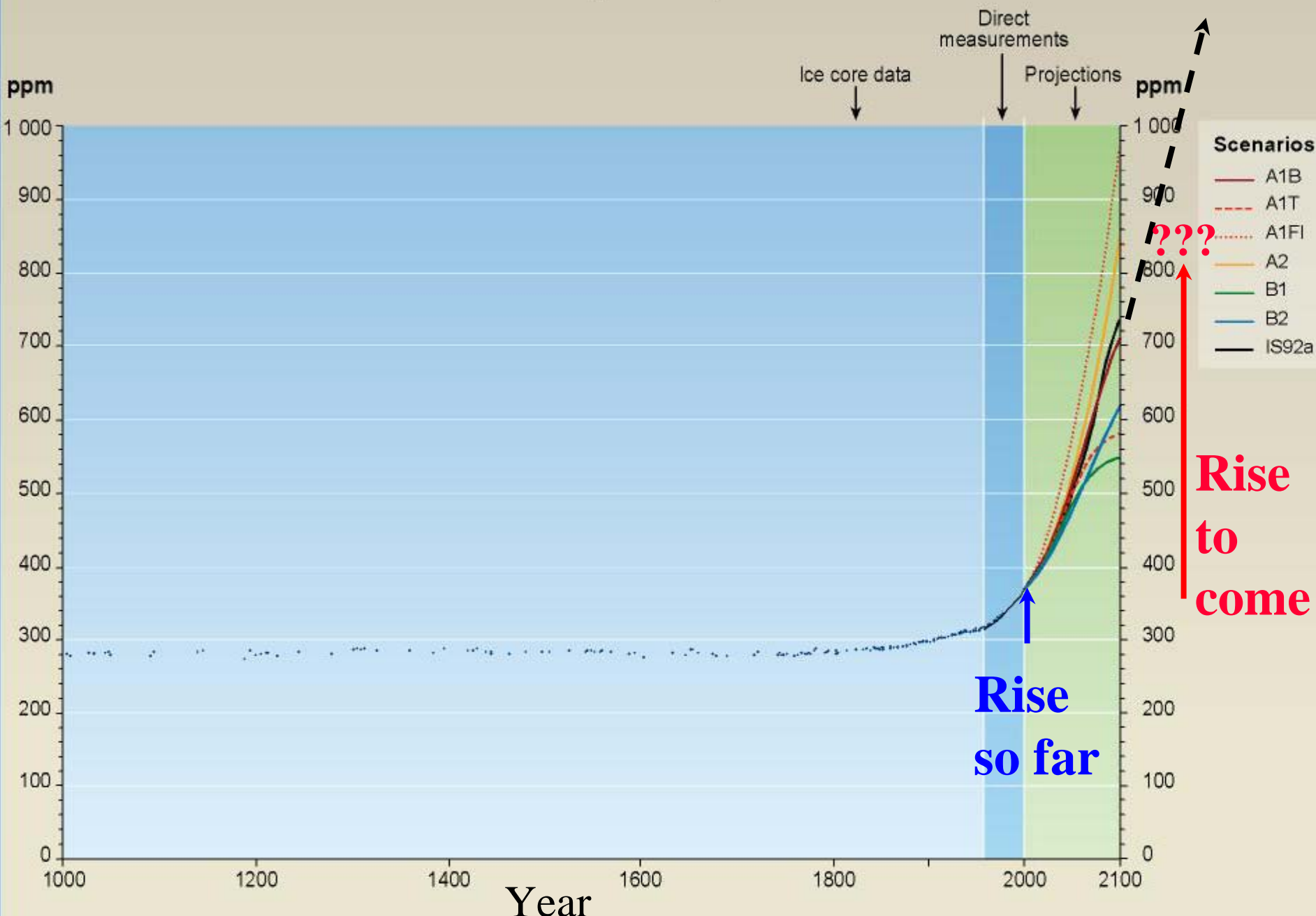
We are forcing warming

This is just a cartoon--others will change, but CO₂ dominant



Past and future CO₂ atmospheric concentrations

???



IPCC, 2001

Multi-model Averages and Assessed Ranges for Surface Warming

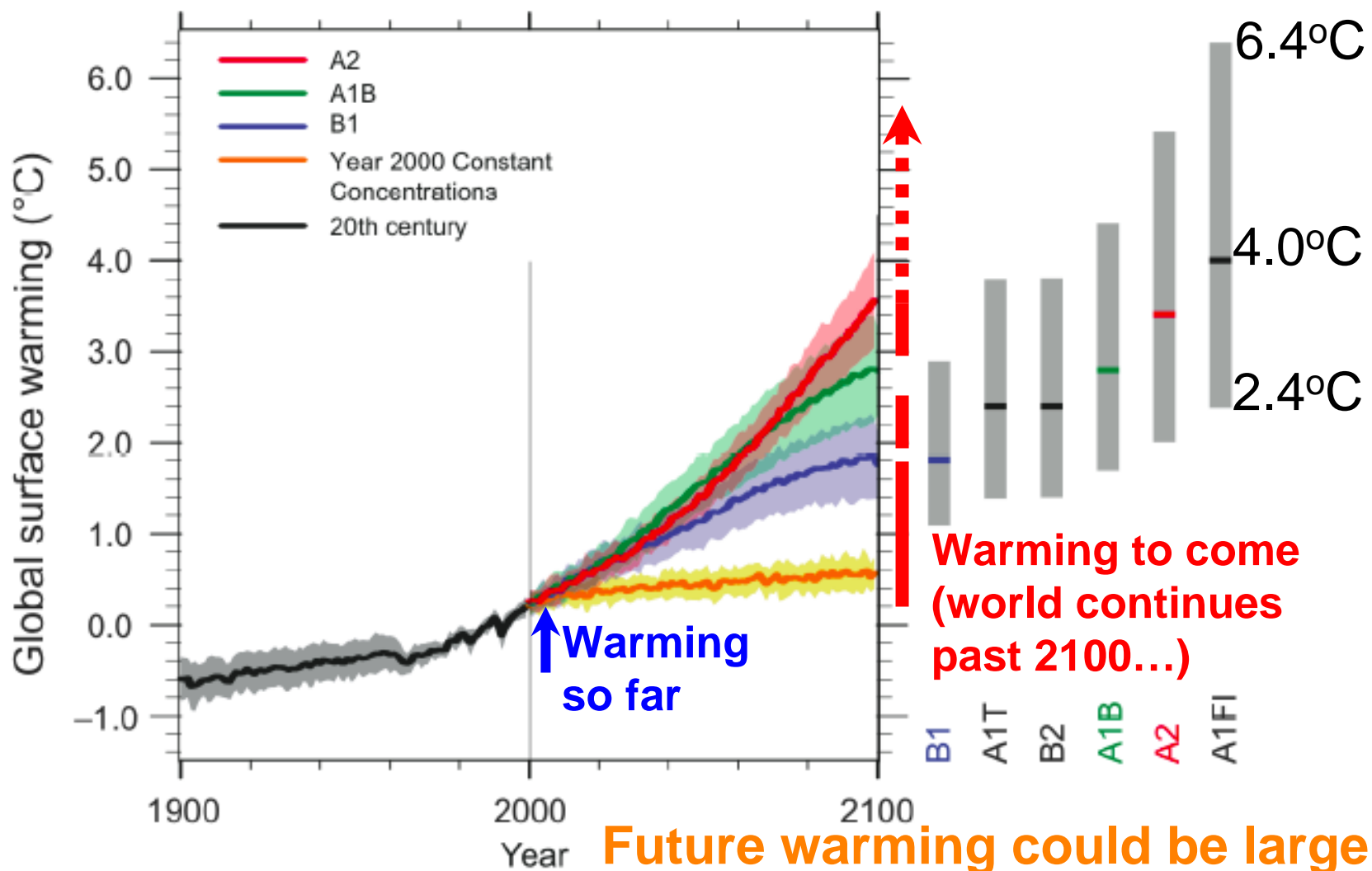
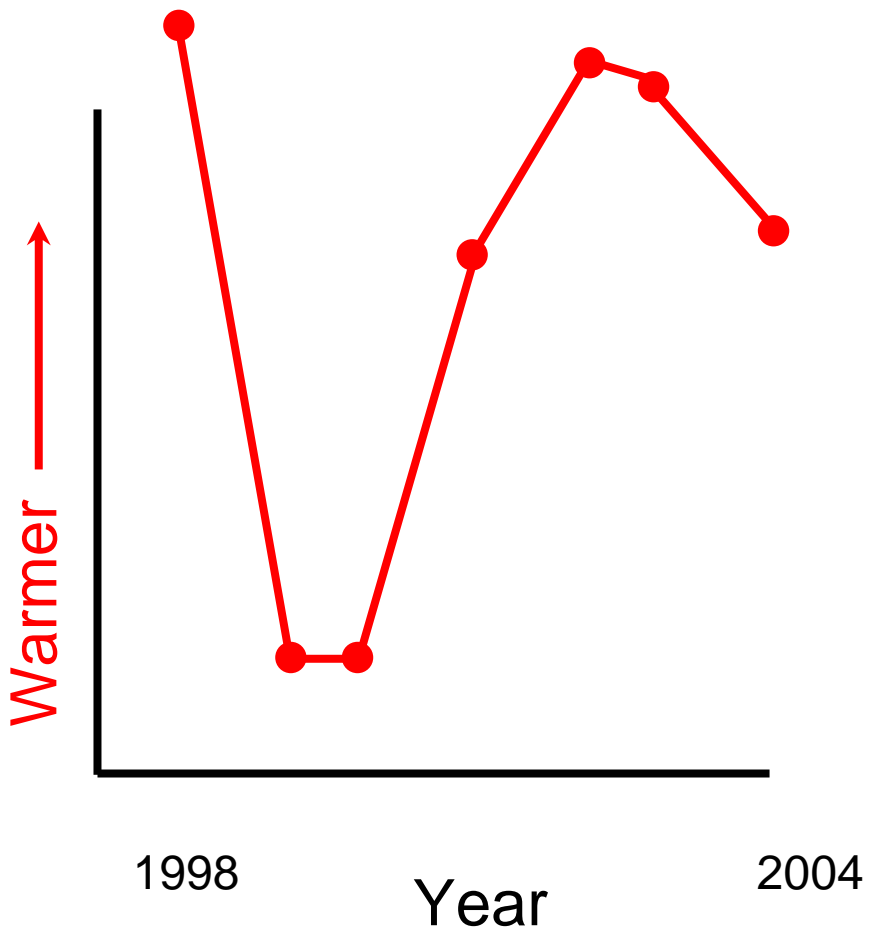


FIGURE SPM-5. Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}

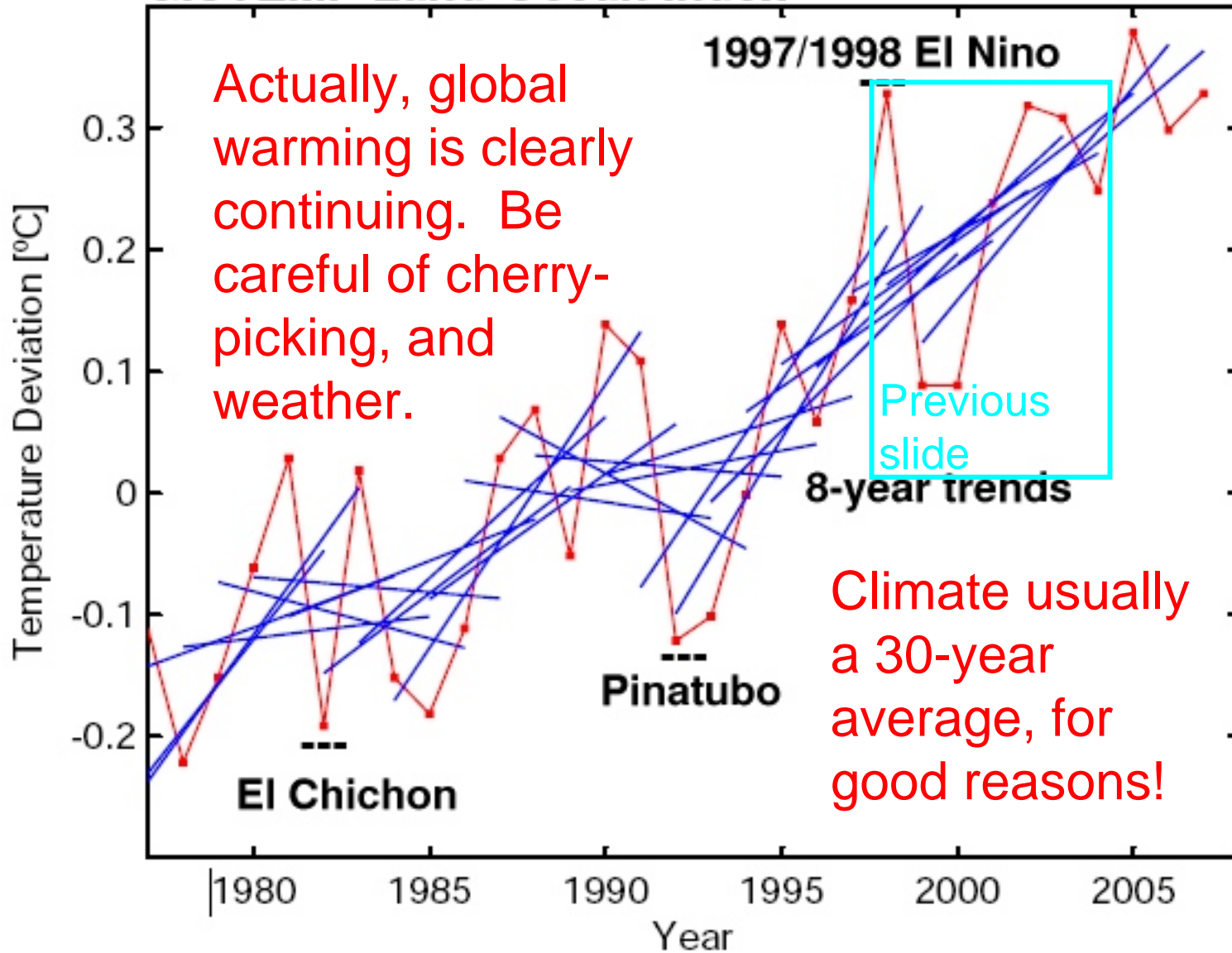


Has global warming stopped?

Here are temperatures from 1998 to 2004, from GISTEMP.

No warming there, right???

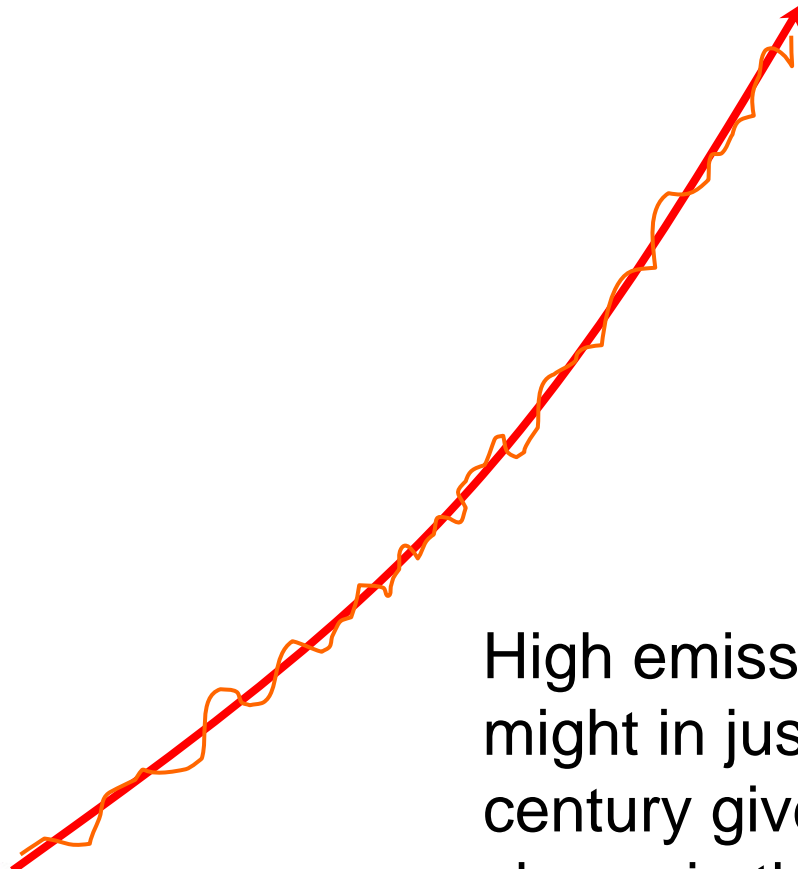
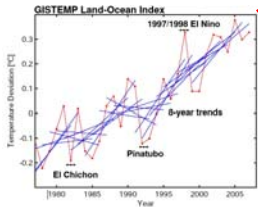
GISTEMP Land-Ocean Index



Source: Gavin Schmidt, NASA GISS

<http://www.realclimate.org/index.php/archives/2008/01/uncertainty-noise-and-the-art-of-model-data-comparison/#more-523>

Previous
slide



High emissions scenarios
might in just over a
century give the warming
shown in this cartoon...

Brief summary of impacts:

- Grain-belt drying for crops
- Sea-level rise
- Tropical diseases no longer frozen
- Loss of unique ecosystems, especially with humans in way of migration
- Tropical cyclones that form likely to become larger (more energy/fuel)
- Tendency for more floods and more droughts (more water in air; faster drying)

Economics (Summarizing experts)

- Damages grow to a few percent of world economy per year (1%≈\$500 billion)
- Fix ≈1% of world economy per year, after a few decades of serious effort and investment in learning how
- Couple climate model to economic model, says that to optimize economy, start to invest now, then ramp up (e.g., Nordhaus)

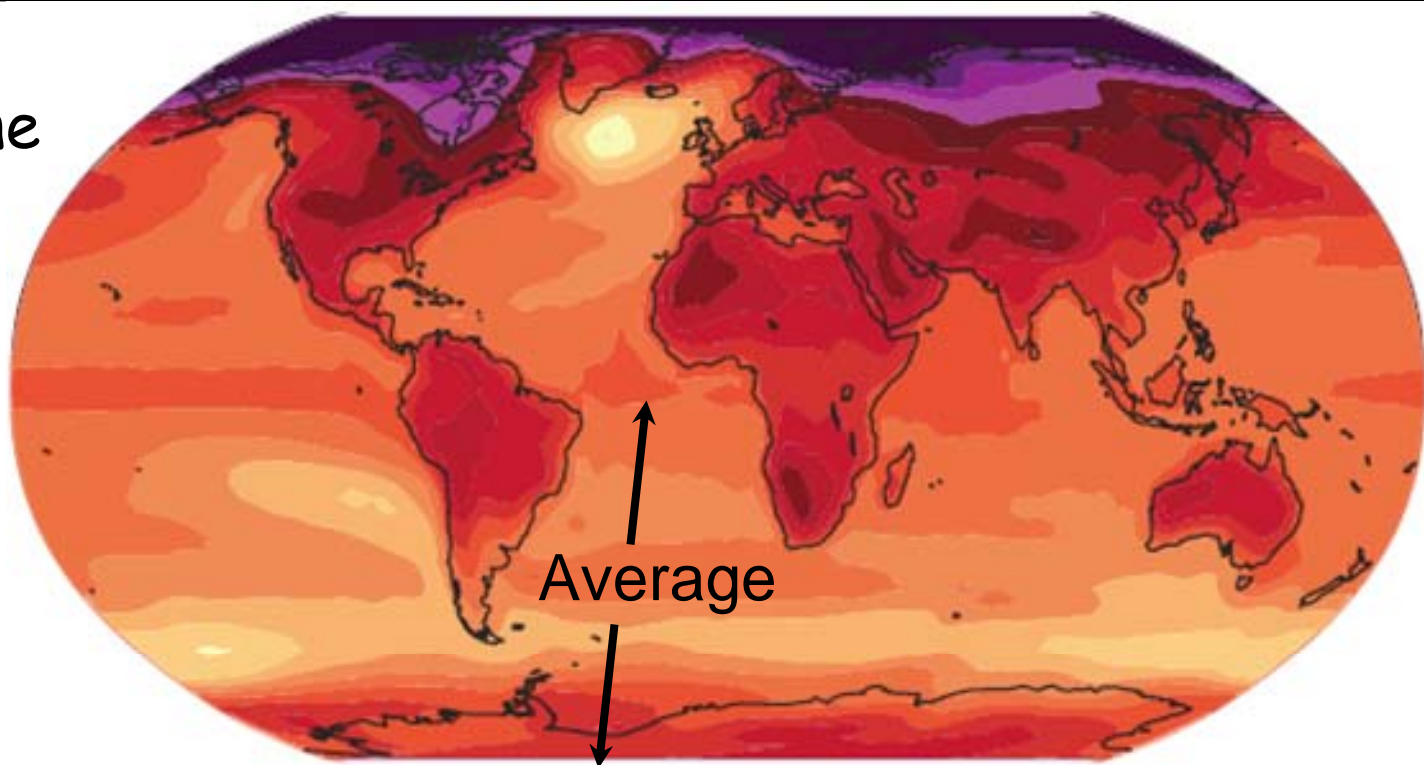
An issue of fairness?

- If you have winter, air conditioners, and bulldozers, a little warming may help economy (too much hurts); if missing any of these, all warming hurts;
- Most warming being caused by people with winter, air conditioning and bulldozers;
- Our emissions hurting others more than us-
- "It's the poorest of the poor in the world...who are going to be the worst hit"
(Rajendra Pachuri, chair, IPCC);
- We legally must clean up toilets, some things from smokestacks so others can drink and breathe...

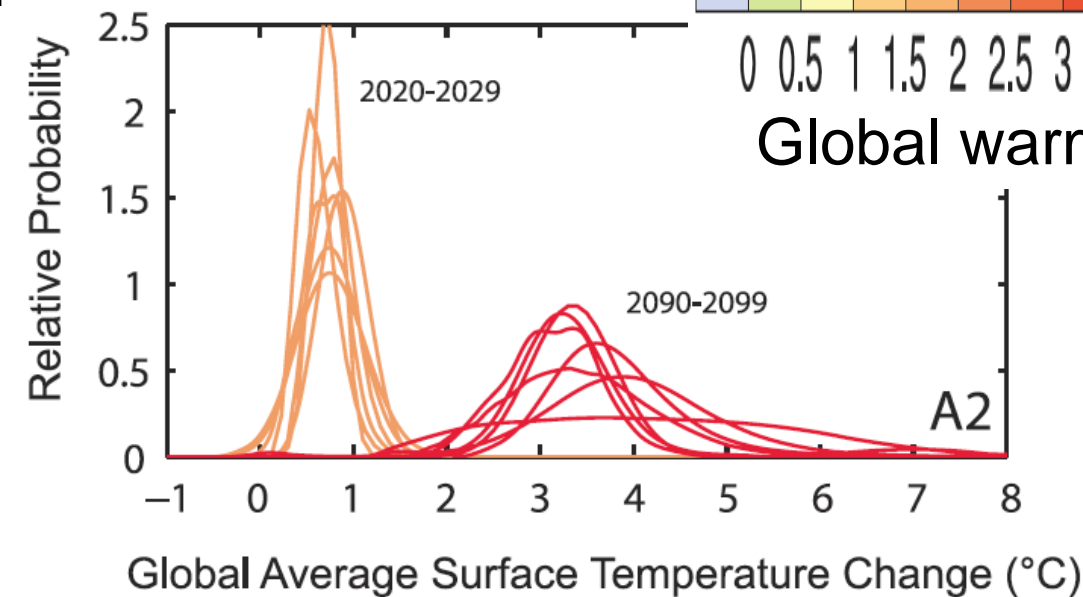
If this picture is wrong, it probably is optimistic:

- Models more often underestimate than overestimate past changes (my view of science);
- Projections smooth but world isn't; abrupt changes harder to handle (north Atlantic shutdown, droughts, ice-sheet collapses, etc.);
- Skewed climate sensitivity (typically, estimates of warming give central estimate, possibility of slightly better, slightly worse, or much worse)
- “uncertainties imply a more stringent set of greenhouse-gas controls than are implied by the best-guess case” W. Nordhaus, *Managing the Global Commons*, 1998.

Lake Wobegon:
Almost everyone
experiences
above-average
warming (most
people live on
land, which
warms faster
than global
average).



0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
Global warming, °C, to 2095



With chance of a little
better, a little worse,
or a lot worse.

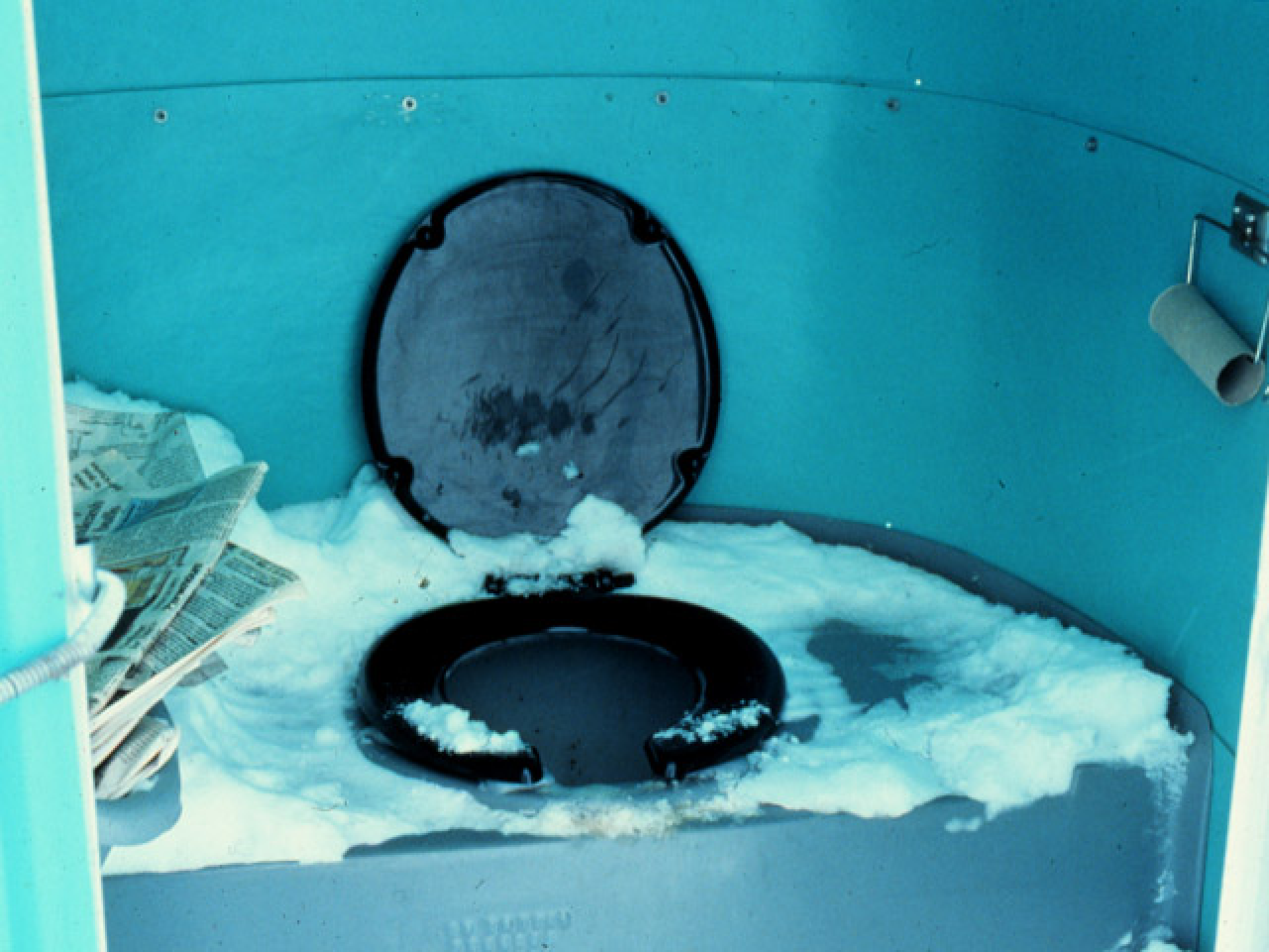










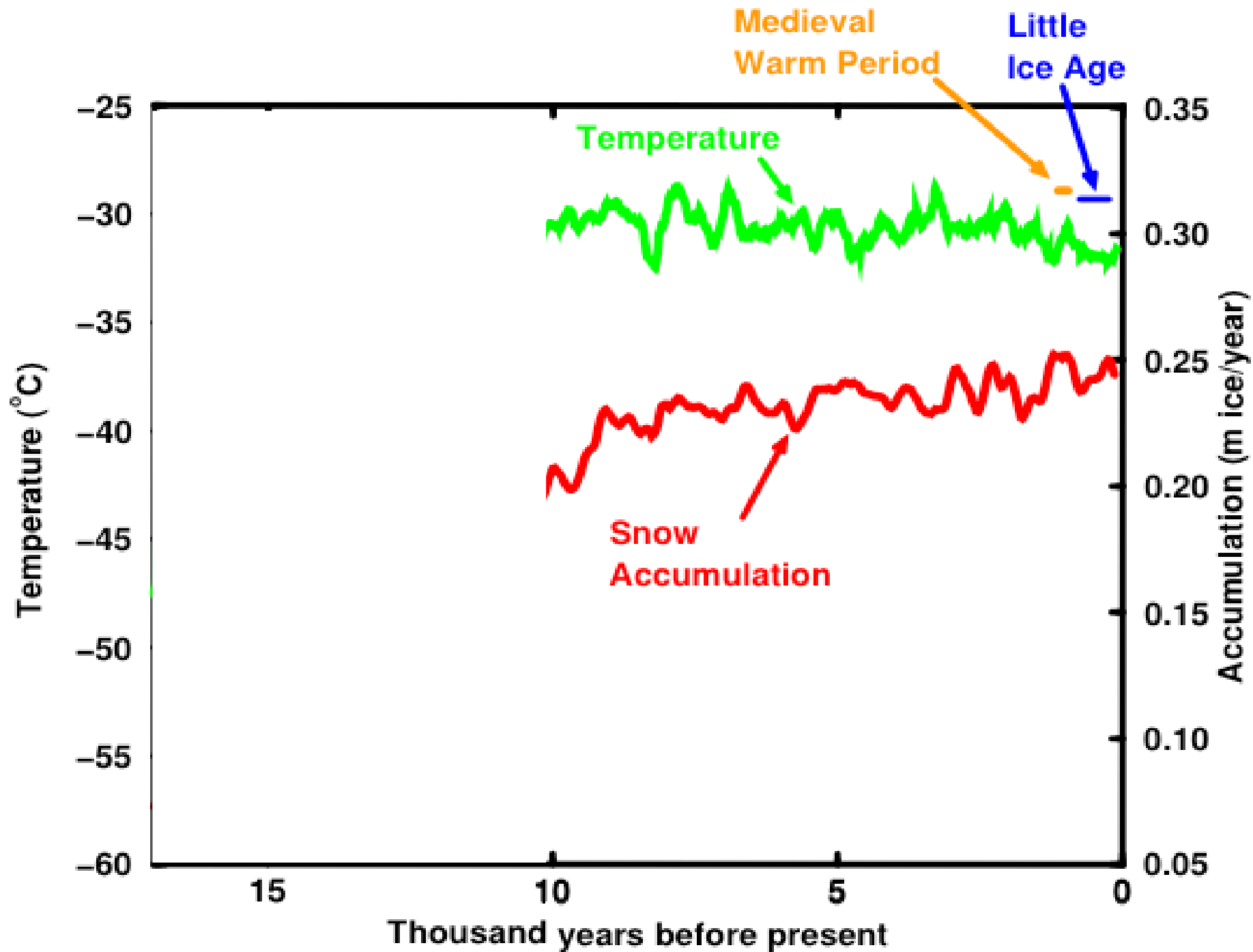


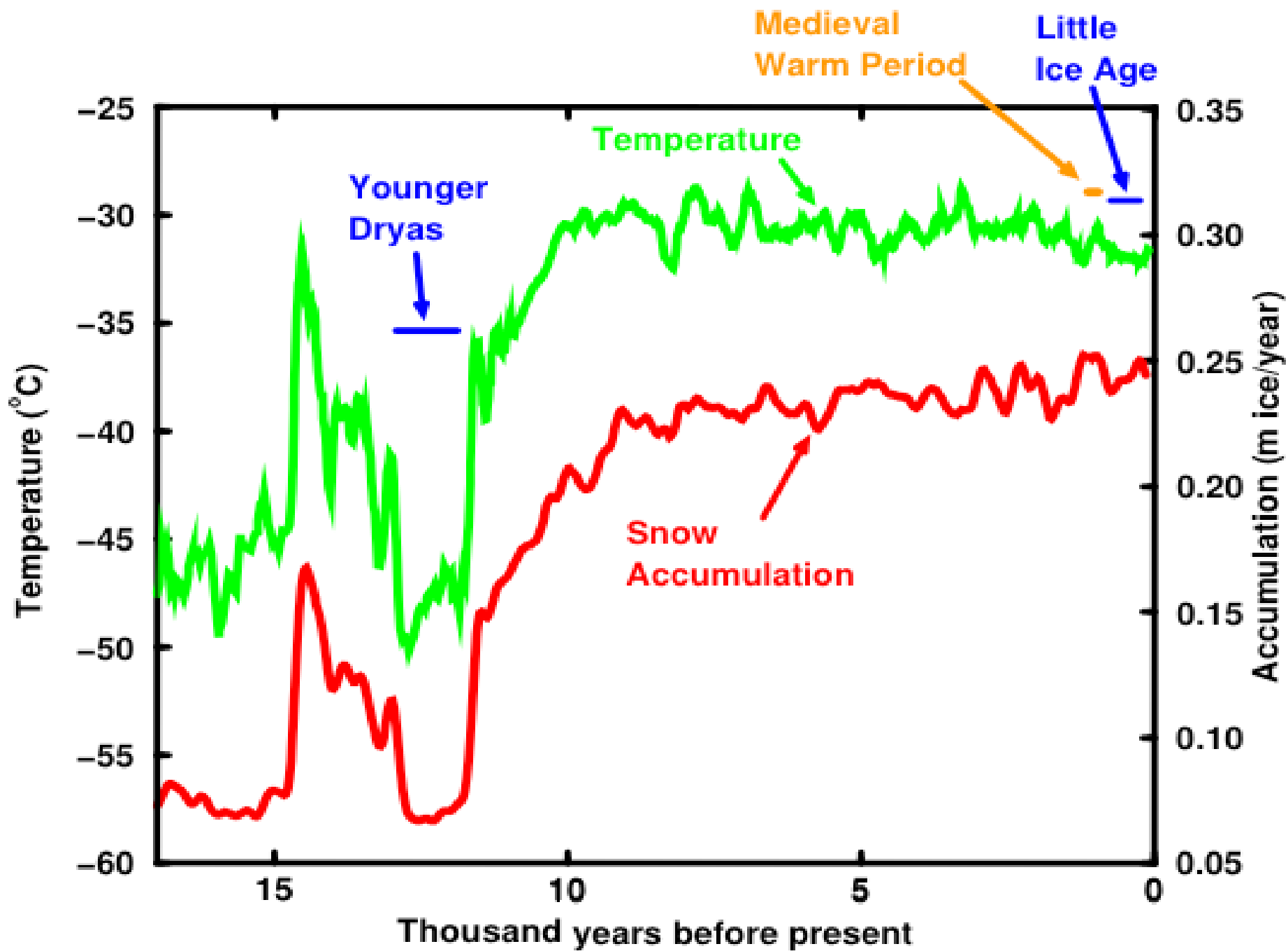


**Penn Staters Kurt Cuffey,
Wanda Kapsner studying ice
cores, central Greenland (NSF-
sponsored GISP2 project)**

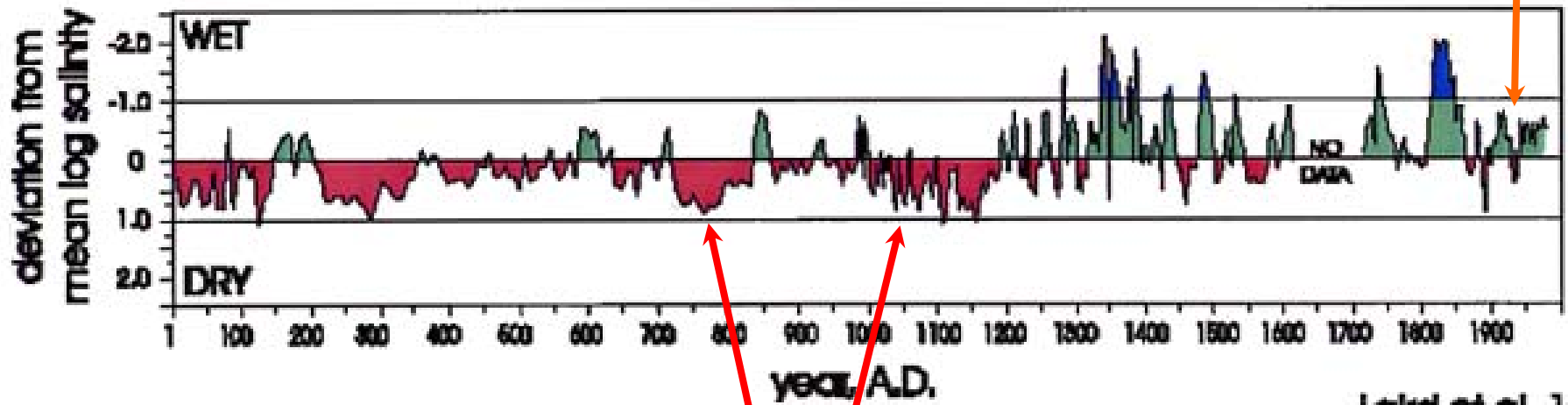








SALINITY as a MEASURE of DROUGHT, MOON LAKE



Laird et al. 1996

DROUGHTS









NSF US
Antarctic
Program (Penn
Staters Don
Voigt, Huw
Horgan, Sridhar
Anandakrishnan



<http://svs.gsfc.nasa.gov/vis/a000000/a002400/a002421/index.html>

**Antarctic Peninsula
(gothic cathedral)**

Ocean

Island

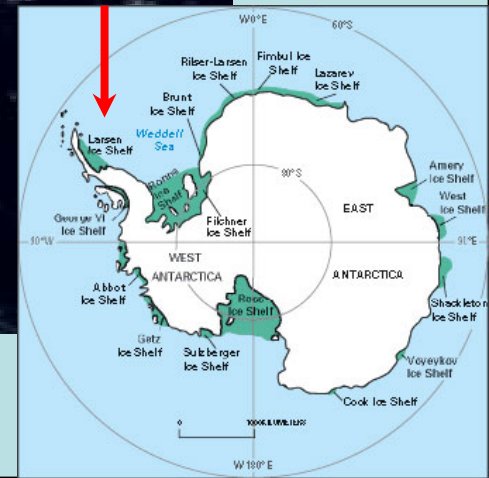
12 mi
20 km

**Melt
ponds**

Icebergs

**Larsen B Ice Shelf
(flying buttress)**

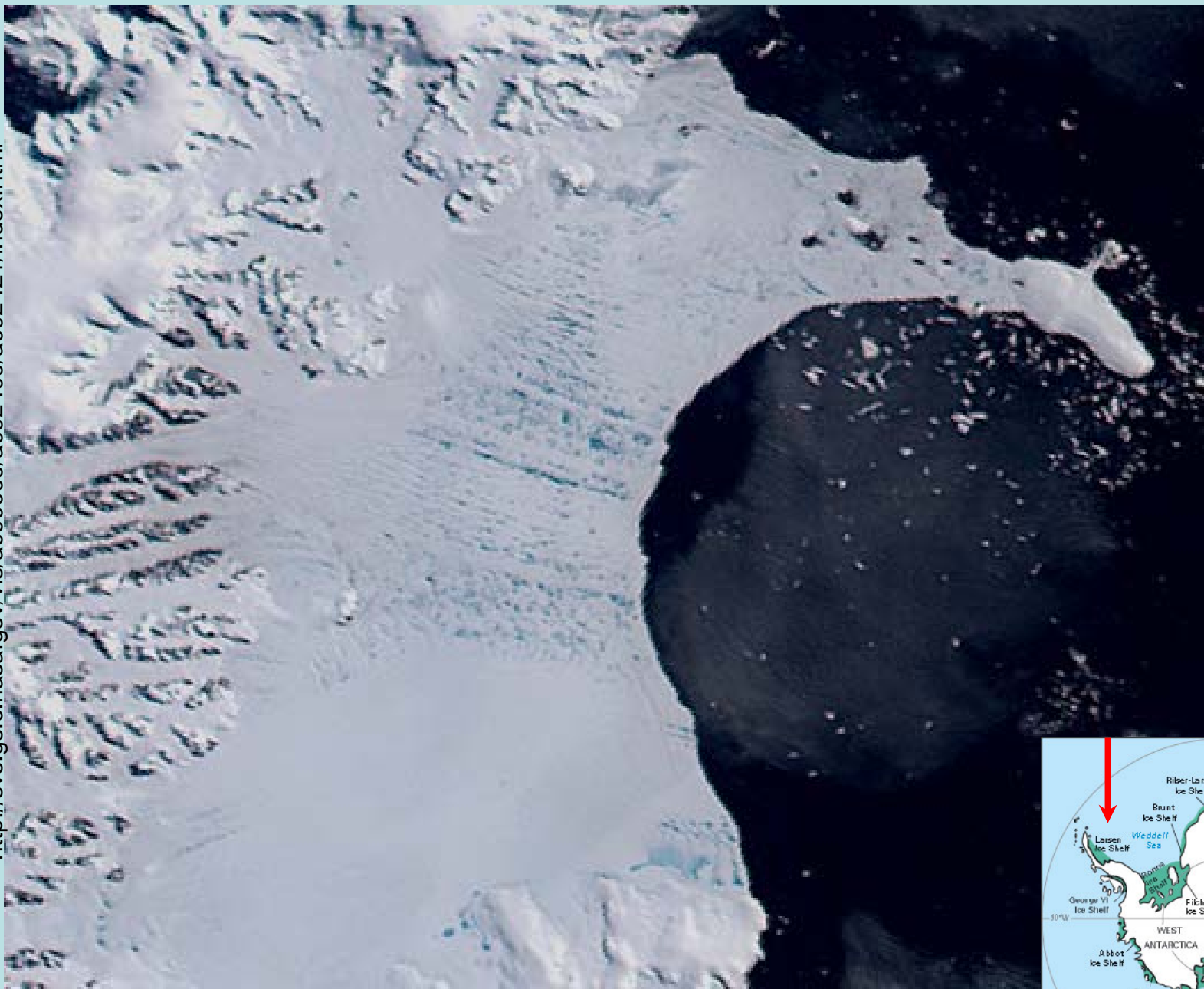
Island



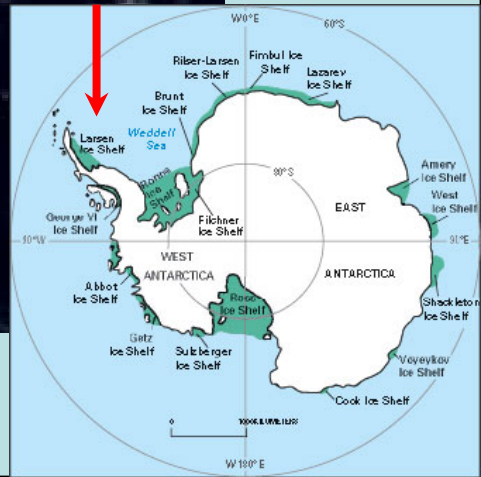
January 31, 2002

Images from NASA

<http://svs.gsfc.nasa.gov/vis/a000000/a0002400/a0002421/index.html>

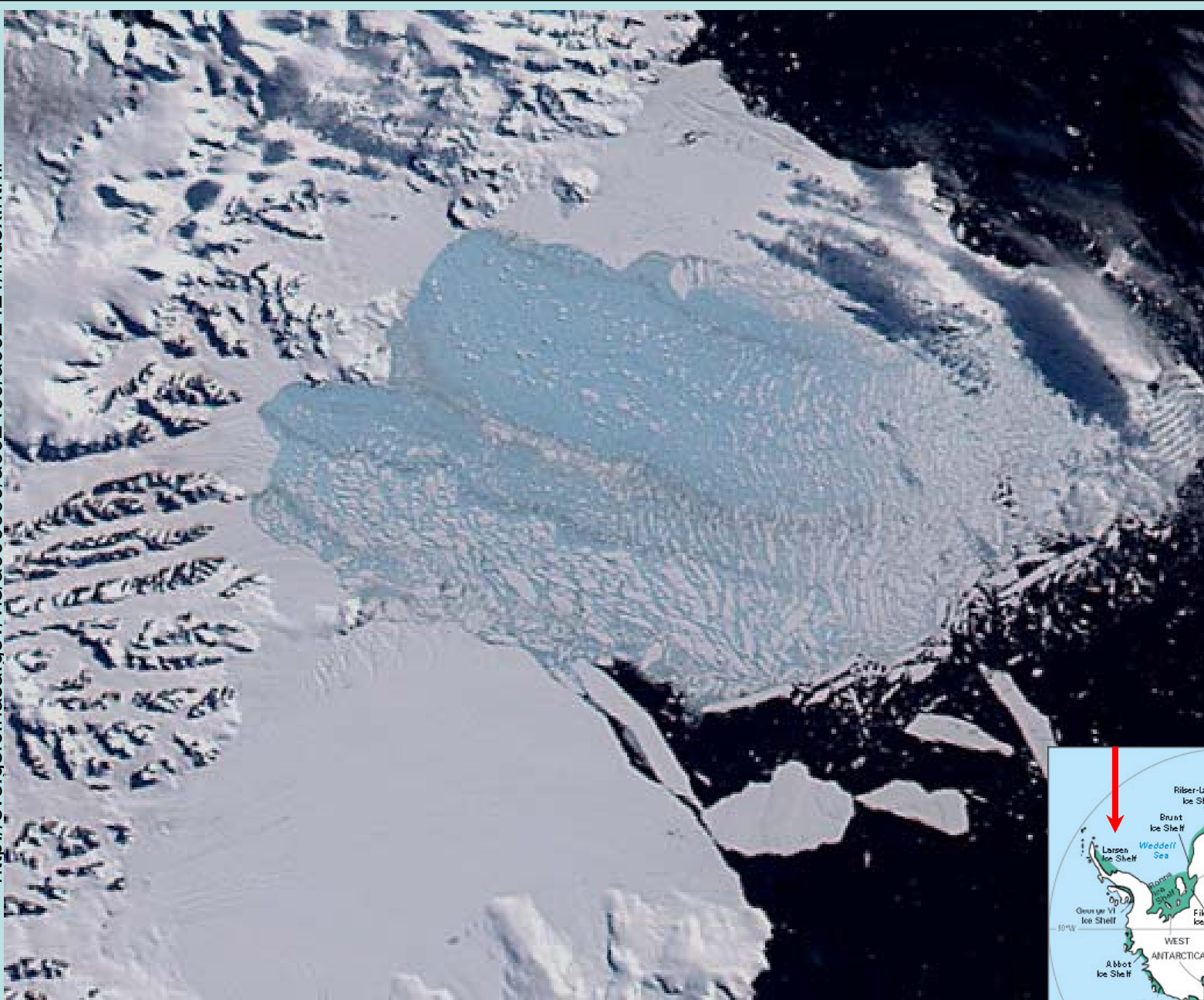


12 mi
20 km



January 31, 2002

<http://svs.gsfc.nasa.gov/vis/a000000/a002400/a002421/index.html>



12 mi
20 km



March 7, 2002. **8x tributary flow-speed increase followed**

IPCC on ice sheets:

- 2001: much uncertainty, but expected snowfall to rise more than melting, little change in flow, net growth 21st century;
- Then: ice sheets responded to warming by shrinking, with ice-flow accelerations;
- 2007: **“Models used to date do not include...the full effects of changes in ice sheet flow, because a basis in published literature is lacking... understanding of these effects is too limited to... provide a best estimate or an upper bound for sea level rise.”**



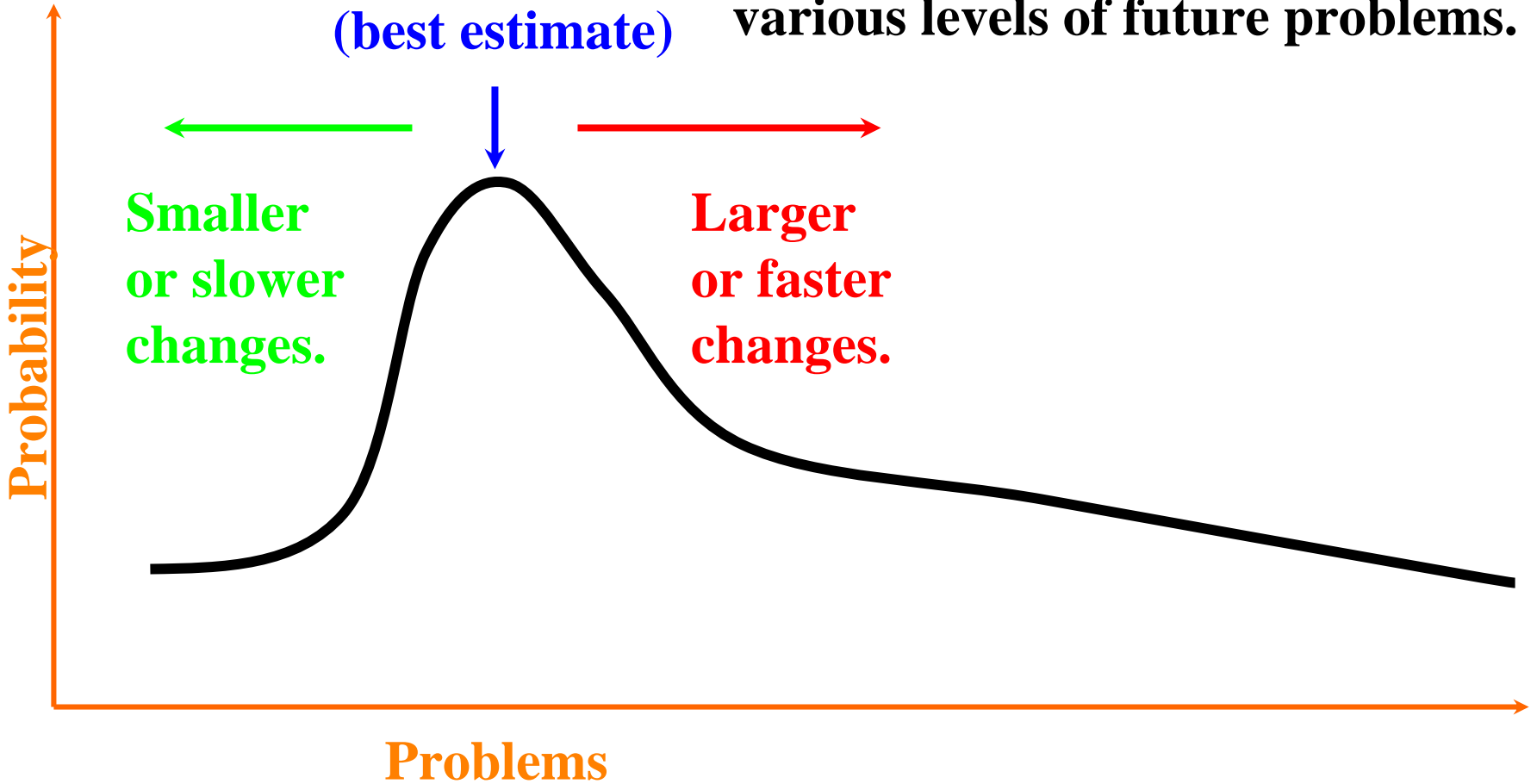
No agreed-upon worst case; maybe 3-4x this rise?
Don't believe this could happen faster than centuries, but we might in decades reach the level that would commit us to this over centuries. Generally NOT in cost/benefit projections.

If you commute by car:

- Most likely: slowed a bit by traffic, only some songs on radio good, arrive ok;
- Best: save a few minutes, great songs;
- Worst: get run over by a semi;
- Many things in life easy to make much worse, hard to make much better;
- (I have insurance for just such things.)

My interpretation of probability of various levels of future problems.

**UN-IPCC
(best estimate)**



Most US debate seems to pit “UN-IPCC best estimate” against “smaller or slower changes”; most of the room seems to be in “larger or faster changes”.

Some OPINIONS:

- We're weeds; we'll be here (but some of the things we love may or may not be);
- Under current trends, hard to imagine how fossil fuel will be common enough and cheap enough for many (most?) of the world's people to get what we have;
- In developing the technical and social know-how to generate more economic activity from less energy, and to generate more energy sustainably, we might "leapfrog" this fossil-fuel problem and actually make a better lifestyle available to others as well as to us.

Some Money?

- Estimates of costs to solve global warming typically ~1% of world economy per year, to avoid much larger damages;
- 1% is nearly \$500 billion/year;
- But realistically involves changing somewhat more of the economy--a few \$trillion/year?
- Past solutions have become successful parts of the economy--plumbing, not chamber pots; integrated pest management, not DDT;
- Sometimes, solving a big problem opens a bigger market (IBM=BUSINESS machines, but we do use computers for other things...)

My personal summary of IPCC Summary for Policymakers (WG1, AR4):

***The best available scientific evidence shows that human fossil-fuel burning and other activities are altering the composition of the atmosphere, causing warming, sea-level rise, and other climatic changes, and that human decisions will determine whether or not future changes are much larger than those that have already occurred.

→Uncertainties remain, but I see no serious problems with or alternatives to this statement.

→And, averaging across uncertain but possible outcomes makes the picture more challenging, and by most metrics is a goad to action, not inaction.

